Ecology of the Oriental Fruit Fly, Melon Fly, and Mediterranean Fruit Fly (Diptera: Tephritidae) on the Island of Ni'ihau, Hawai'i

ROGER I. VARGAS

Tropical Fruit and Vegetable Research Laboratory, USDA-ARS, P.O. Box 2280, Honolulu, Hawai'i 96804, USA

ABSTRACT. Ni'ihau Island, Hawai'i, was surveyed for the first time for Mediterranean fruit fly, *Ceratitis capitata*, Oriental fruit fly, *Bactrocera dorsalis*, and melon fly, *Bactrocera cucurbitae*. Populations of all three species were low compared to nearby Kauai Island. Overall annual mean (± SD) capture rates for Oriental fruit fly, melon fly, and Mediterranean fruit fly were 2.5 ± 3.2, 3.9 ± 6.2, and 0.003 ± 0.004 flies per trap per day, respectively, for 1990 (n = 7 traps); 12.5 ± 15.5, 8.8 ± 10, and 0.05 ± 0.14 flies per trap per day for 1991 (n = 7 traps); and 8.4 ± 13.4, 6.1 ± 9.5, and 0.01 ± 0.01 flies per trap per day during 1992 (n = 10 traps). On the basis of variance/mean relationships, Oriental fruit fly and melon fly distributions were highly aggregated (variance/mean > 1), apparently in response to the presence of localized concentrations of host fruits. Oriental fruit fly and Mediterranean fruit fly populations were centered in the village of Pu'uwai where fruit trees were common near houses and at Kiekie where an experimental coffee (*Coffea arabica*) field was being cultivated. Melon fly populations were centered in wild cucurbits areas.

INTRODUCTION

Ni'ihau Island (21°55'N, 160°10'W), Hawai'i, located 27.4 km sw of Kaua'i Island, is elliptical (29 km long by 9.7 km wide) in shape and comprises an area of 189 km^2 with a maximum elevation of 390 m near Pani'au (Armstrong 1983, Wichman & St. John 1990). The central and eastern parts of the island are upland remnants of a single volcanic dome, which on the east forms abrupt sea cliffs and on the west slopes down to a coastal plain (Wichman & St. John 1990). Bordering the volcanic mass on the north, west, and south is a low plain with a maximum elevation of 30.5 m at the base of the highland cliffs (Hinds 1930). Because of its location in the lee of Kaua'i and low elevation, rainfall ranges only 25.4–102 cm/year (Armstrong 1983). Although Ni'ihau is dry most of the year, southern storms occur commonly during the winter creating intermittent lakes such as Halali'i Lake, the largest natural lake in Hawai'i (Armstrong 1983).

The original vegetation of Ni'ihau has been decimated by grazing of goats, sheep and cattle (Wichman & St. John 1990). The present vegetation is dominated by kiawe, *Prosopis pallida* (Humb. & Bonpl. ex Willd.) Kunth, which forms dry, open, sparse stands over both the lowlands and uplands. On the western side of the lowland and on the mountain upper ridge there are areas of dry grassland. At the north end of the the mountain ridge there is a dense thicket of haole koa, *Leucaena leucocephala* (Lam.) de Wit (Wichman & St. John 1990).

Beardsley & Tuthill (1959) reported Oriental fruit fly (OFF), *Bactrocera dorsalis* (Hendel), to be present on Ni'ihau Island. However, little else is known about fruit flies inhabiting Ni'ihau. Therefore, in 1990 I began a study of the distribution and relative abundance of Oriental fruit fly, melon fly (MF), *Bactrocera cucurbitae* (Coquillett), and Mediterranean fruit fly (MFF), *Ceratitis capitata* (Wiedemann). I wanted to determine: 1) if all 3 species of fruit flies were present on Ni'ihau; 2) the seasonal population trends of species present; 3) areas where fruit fly populations concentrate; and 4) the major factors associated with fly distribution.

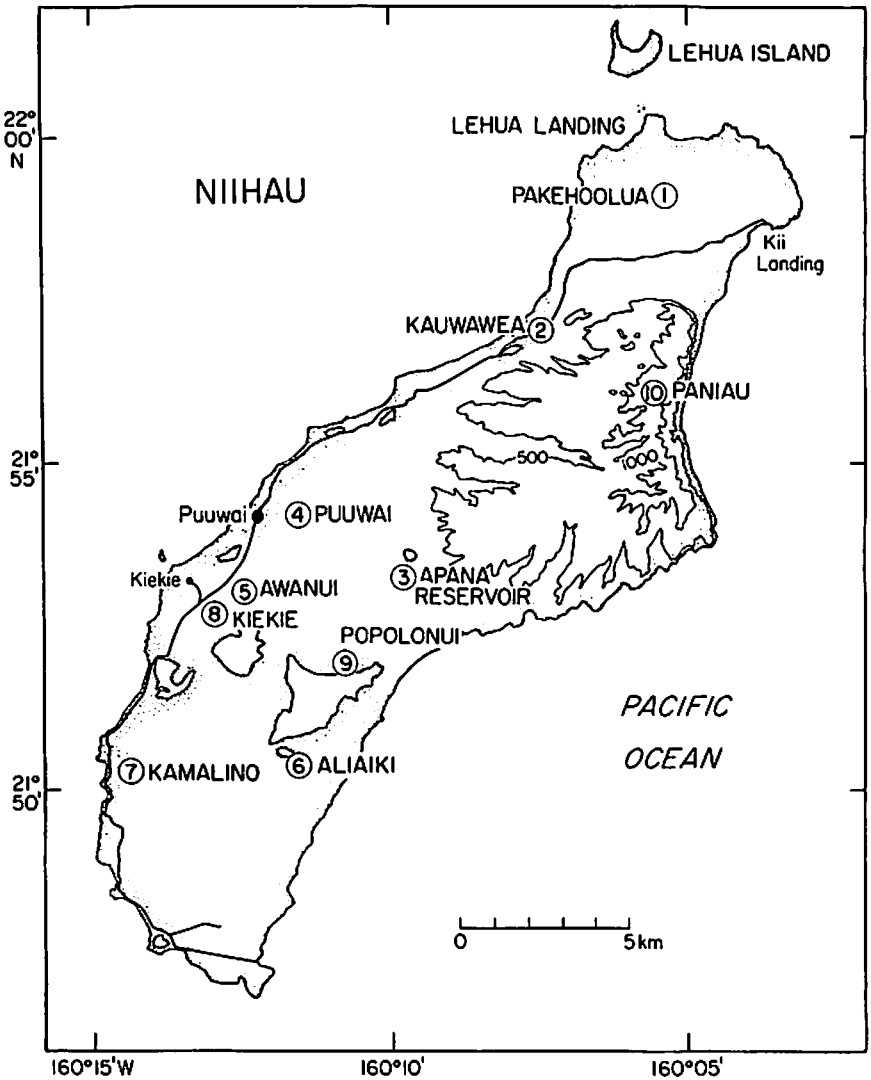

Fig. 1. Map of the island of Niihau showing trap sites.

MATERIALS AND METHODS

Study Sites

In January 1990, I established 7 study sites (traps 1–7) in the north, central, and south sections of the island (Fig. 1). In January 1992, 3 additional trap sites were added to the survey to include a coffee (*Coffea arabica* L.) patch at Kiekie, a lakeside scrub forest at Popolonui and an upland site at Pani'au (traps 8, 9 & 10, respectively). Habitat type and dominant plants for survey sites are summarized in Table 1. Mediterranean fruit fly, OFF, and MF traps (Vargas et al. 1983a, 1983b, 1989; Harris et al. 1986) containing wicks sat-

urated with 8 ml (95% lure + 5% naled) trimedlure, methyl-eugenol, or cue-lure, respectively, were set at each site. When encountered, host fruits were collected and held according to the methods of Vargas et al. (1983a).

Table 1. Trap locations and habitat type.

Trap No.	Location	Habitat	Dominant Plant
1	Pakeho'olua	Xerotropical scrub savannah	Kiawe, teasel gourd (*Cucumis dipsaceus* Ehrenberg ex Spach)
2	Kauwawea	Xerotropical scrub savannah	Kiawe, teasel gourd
3	Apana Reservoir	Xerotropical scrub	Kiawe
4	Pu'uwai	Village	Kiawe, mango (*Mangifera indica* L.), teasel gourd
5	Awanui	Rangeland	Kiawe, mango
6	Aliaiki	Xerotropical scrub savannah	Kiawe
7	Kamalino	Xerotropical scrub savannah	Kiawe
8	Kiekie	Coffee plot	Coffee, kiawe
9	Popolonui	Scrub forest	Kiawe
10	Pani'au	Upland scrub	Kiawe

Statistical Methods

Insects were removed from traps and counted monthly. Trap captures were expressed as mean (± SD) number of flies caught per trap per day, total flies, or percent of the total flies captured. Variation among trap sites and months during each year of the study was assessed by 2-way analysis of variance after $ln(x+1)$ transformation of the data. Orthogonal contrasts were employed for means comparisons. A 0.05 probability level served as the significance criterion for all statistical tests (SAS 1985).

RESULTS

Three years of trap data indicated that OFF and MF were present throughout the year on Ni'ihau. Mediterranean fruit fly was trapped sporadically. Seasonal population fluctuations (flies/trap/day) during 1990, 1991, and 1992 for all 3 fruit fly species are presented (Fig. 2).

Oriental Fruit Fly

In 1990, trap captures of OFF varied significantly among both traps ($F_{6,66} = 16.297$; $P < 0.001$) and months ($F_{11,66} = 2.609$; $P < 0.01$). Two of the 3 planned comparisons were significant; captures differed between traps 1 and 2 in the north savannah habitat, and between traps 4 and 5 in the central inhabited coastal area. Traps 6 and 7, in the south savannah area, did not differ in trap captures. Greatest numbers of flies were captured in January–February; captures in these months were not significantly different ($P > 0.50$), but were significantly greater than the average capture rates throughout the following nine months ($P < 0.001$) until the increases observed in December.

Oriental fruit fly captures in 1991 again varied significantly among both traps ($F_{6,66} = 14.183$; $P < 0.001$) and months ($F_{11,66} = 21.193$; $P < 0.001$). In contrast to 1990, however, the only significant planned comparison was that between traps 4 and 5; captures in

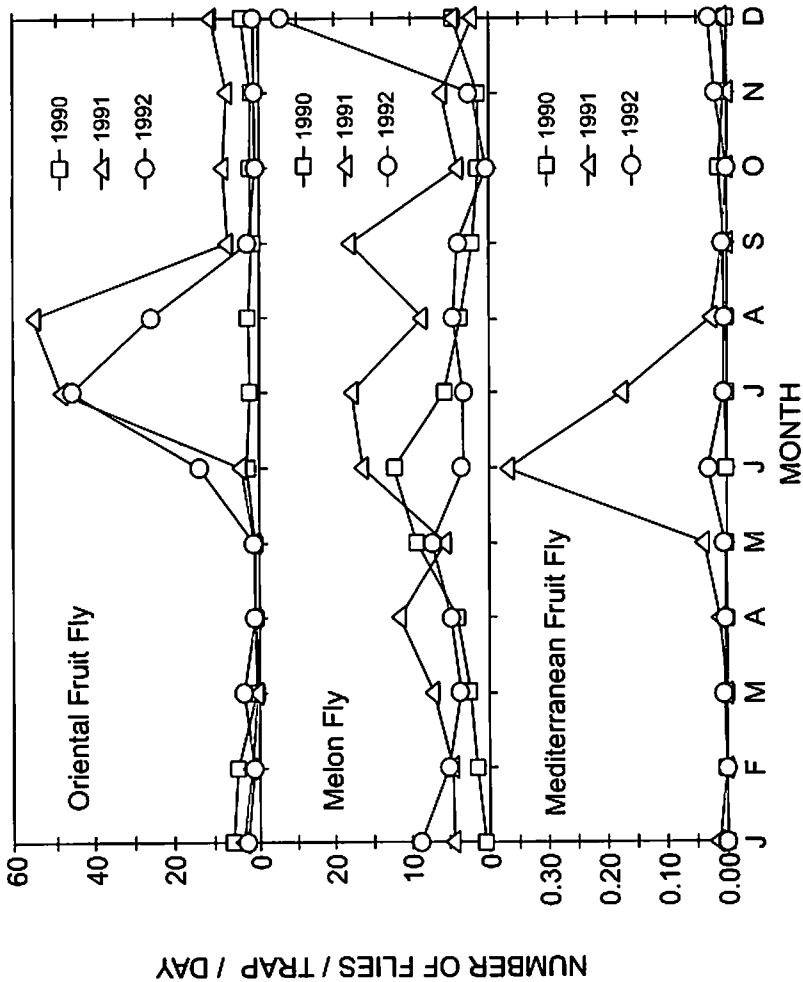

Fig. 2. Seasonal population fluctuations of Oriental fruit fly, melon fly, and Mediterranean fruit fly from 1990 until 1992.

Table 2. Dispersion indices of Oriental fruit fly (OFF), melon fly (MF), and Mediterranean fruit fly (MFF) based on mean (± SD) annual capture.

Species	Year	Mean ± SD	Variance / Mean
OFF	1990	2.5 ± 3.2	4.1
	1991	12.5 ± 15.5	19.2
	1992	8.4 ± 13.4	21.4
MF	1990	3.9 ± 6.2	38.4
	1991	8.8 ± 10.0	11.4
	1992	6.1 ± 9.5	14.8
MFF	1990	0.003 ± 0.004	0.01
	1991	0.05 ± 0.14	0.39
	1992	0.01 ± 0.01	0.01

Table 3. Percent of total Oriental fruit fly (OFF), melon fly (MF), and Mediterranean fruit fly (MFF) captured on Ni'ihau during 1990, 1991, and 1992.

			Trap Number									
Sp.	Year	Total	1	2	3	4	5	6	7	8	9	10
OFF	1990	6959	2.1	27.2	10.5	49.9	5.5	3.1	1.8	-	-	-
	1991	30722	6.6	8.3	10.4	51.9	15.9	3.1	3.9	-	-	-
	1992	30313	1.0	3.5	4.5	51.8	14.4	1.4	0.7	15.3	1.8	5.6
MF	1990	10399	0.2	62.3	4.7	23.2	5.8	2.0	1.9	-	-	-
	1991	23300	1.2	38.4	18.8	34.1	5.0	0.6	1.8	-	-	-
	1992	24336	1.8	42.0	3.3	7.3	0.7	0.4	0.4	6.5	1.3	36.3
MFF	1990	7	0.0	0.0	0.0	57.1	28.6	14.3	0.0	-	-	-
	1991	132	0.0	0.0	0.0	94.7	3.8	0.0	1.5	-	-	-
	1992	32	0.0	9.4	0.0	40.6	6.3	6.3	0.0	31.3	0.0	6.3

the former exceeded those of the latter by more than threefold, even though trap 5 captures were greater than all others. Temporal variation consisted of fluctuations at low capture levels from January–June, followed by a significant increase in July–August ($P < 0.001$), and subsequent significant decrease ($P < 0.001$) in the final 4 months of the year.

The 1992, OFF trap captures again varied significantly among both traps ($F_{9,99} = 11.824$; $P < 0.001$) and months ($F_{11,99} = 11.667$; $P < 0.001$). As in 1991, captures in trap 4 were greatly in excess of trap 5 ($P < 0.001$). The differences between captures in traps 1 and 2 and traps 6 and 7 were not significant (both contrasts $P > 0.05$). The additional contrasts planned for 1992 revealed no clear elevation effect on trap captures of OFF; numbers in traps 2 and 10 and in traps 9 and 10 were not significantly different (both contrasts $P > 0.25$), whereas the tenfold difference between captures in traps 4 and 10 was highly significant ($P < 0.001$). Temporal variation again consisted of fluctuations at low levels in winter and spring, followed by a significant increase in June ($P < 0.005$) and a further increase in July ($P < 0.001$) to high summer levels, and a decrease beginning in August ($P < 0.05$) to low autumn levels. Populations were highest in June, July, and August and lowest in March, April, and May.

Overall annual mean (± SD) capture rates for OFF were 2.5 ± 3.2, 12.5 ± 15.5, and 8.4 ± 13.4 flies/trap/day for 1990, 1991, and 1992, respectively. On the basis of variance/mean relationships, fly distributions were highly aggregated (variance/mean > 1)

(Table 2). Total captures for OFF for all traps on Ni'ihau were 6,959, 30,722, and 30,313 flies, during 1990, 1991, and 1992, respectively (Table 3). Of the traps set throughout Ni'ihau, 1 trap captured the majority of oriental fruit flies. The OFF trap at Pu'uwai (trap 4) captured 49.9, 51.9, and 51.8% of the total flies during 1990, 1991, and 1992, respectively. Fruits were relatively scarce in the village during survey trips. However, OFF was reared from mango (*Mangifera indica* L.) fruits (50 fruits, 143 OFF) collected from trees at Pu'uwai during 1991 and from coffee fruits (n = 406 fruits, 15 OFF) collected at Kiekie during 1992 (Table 4). The braconid parasitoid wasp, *Biosteres arisanus* (Sonan), was also reared from OFF pupae.

Table 4. Oriental fruit fly (OFF), melon fly (MF), Mediterranean fruit fly (MFF), and *B. arisanus* (Sonan) reared from fruits collected on Niihau during 1991 and 1992.

Date	Host	No. Fruit	No. Pupae	OFF	MF	MFF	*B. a.*	Eclosion (%)	Parasitism (%)
Mar 1991	Teasel Gourd	50	70	0	48	0	0	68.5	0.0
June 1991	Mango	29	185	143	0	2	17	78.3	9.1
Oct 1992	Coffee	150	28	11	0	6	4	60.7	14.3
Nov 1992	Coffee	256	67	4	0	28	16	47.8	23.9

Melon Fly

The 1990 MF trap captures varied significantly among traps ($F_{6,66}$ = 37.628; P < 0.001) and months ($F_{11,66}$ = 6.146; P < 0.001). Traps 1 and 2 yielded the minimum and maximum catches, respectively, a highly significant difference (P < 0.001), although both were within the same habitat. Trap catches also differed significantly between traps 4 and 5 near houses (P < 0.001). Traps 6 and 7 did not differ in trap captures (P > 0.50). The temporal pattern of the trap catches consisted of low numbers from January–April, followed by a significant increase (P < 0.001) to a May–June maximum, followed by a decrease (P < 0.001) to relatively low levels for the remainder of the year.

Trap captures of melon fly in 1991 differed significantly among traps ($F_{6,66}$ = 6.356; P < 0.001), but temporal variation was not significant ($F_{11,66}$ = 1.011; P > 0.25). Differences were comparable to the prior year; significantly greater captures were obtained in trap 2 than in trap 1 (P < 0.001) and in trap 4 compared to trap 5 (P < 0.005), while the mean catches in traps 6 and 7 were equal.

The 1992, MF trap captures again varied significantly among both traps ($F_{9,99}$ = 18.595; P < 0.001) and months ($F_{11,99}$ = 4.398; P < 0.001). Once again, traps 1 and 2 and traps 4 and 5 differed significantly (both contrasts (P < 0.001), whereas captures in traps 6 and 7 were not significantly different (P > 0.50). The mean catches in traps 2 and 10 were very close, whereas catches in traps 9 and 10 differed almost 28-fold and were significantly different (P < 0.001). Temporal variation was dominated by a significant increase in December (P < 0.001) to a level which was 6.5-fold greater than the average of the prior 11 months.

Overall annual mean (± SD) capture rates for MF were 3.9 ± 6.2, 8.8 ± 10 and 6.1 ± 9.5 flies per trap per day for 1990, 1991, and 1992, respectively. On the basis of variance/mean relationships, fly distributions were highly aggregated (variance/mean > 1).

Total captures for MF for all traps on Ni'ihau were 10,399 (in 1990), 23,300 (1991), and 24,336 (1992). Of the traps set throughout Ni'ihau, 2 traps captured the majority of MF. The trap at Ka'uwa'wea (trap 2) captured 62.3% (1990), 38.4% (1991), and 42.8% (1992) and the trap at Pu'uwai captured 23.2% (1990), 34.1% (1991) and 13% (1992) of the total flies. MF were reared from wild teasel gourds (*Cucumis dipsaceus* Ehrenberg ex Spach) (50 fruits, 48 MF) collected near Ka'uwa'wea during 1991 (Uchida et al. 1990).

Mediterranean Fruit Fly

Mediterranean fruit flies were trapped sporadically during the survey. From 1990–1992, MFF was trapped 5, 8, and 9 months of the year, respectively. Generally, MFF populations were highest from May–September. Overall annual mean (± SD) capture rates for MFF were 0.003 ± 0.004 (1990), 0.005 ± 0.14 (1991), and 0.01 ± 0.01 (1992) flies per trap per day. On the basis of variance/mean relationships, fly distributions were randomly distributed (variance/mean < 1). Total captures for MFF for all traps on Ni'ihau were 7, 132, and 32 during 1990, 1991, and 1992, respectively. Of the traps set throughout Ni'ihau, one trap captured the majority of MFF. The trap at Pu'uwai (trap 4) captured 57.1% (1990), 94.7% (1991), and 40.6% (1992) of the total flies. MFF were reared from coffee (*Coffea arabica* L.) (406 fruits, 34 MFF) collected at Kiekie during 1992.

DISCUSSION

Results indicate OFF is present in small numbers on Ni'ihau Island compared to nearby Kauai Island. Vargas et al. (1983a, 1989, 1990) trapped greater numbers of OFF in the same trap on Kaua'i in a single month than total numbers trapped on Ni'ihau during an entire year. Trap captures and infested mango fruits indicated populations of OFF were centered in the village at Pu'uwai where mango trees were common. Other fruit trees noted in the village were papaya (*Carica papaya* L.) and guava (*Psidium guajava* L.).

Similarly, MF are present in small numbers on Ni'ihau Island compared to Kaua'i Island. Vargas et al. (1989) and Harris et al. (1986) trapped greater numbers of MF in the same trap on Kaua'i in a single month than those trapped on Ni'ihau in an entire year. MF populations were centered in 2 areas: Ka'uwa'wea and Pu'uwai where teasel gourd vines were common. Apparently, this annual herb appears in response to periods of rain. Other wild cucurbits common on Ni'ihau were bitter melon, *Momordica charantia* L., and *Sicyos niihauensis* St. John. Although these genera are commonly infested by MF on other islands (Uchida et al. 1990), sufficient fruits were not available during the survey on Ni'ihau to make a determination.

During 1990 it was not clear whether MFF was a permanent or temporary resident of Ni'ihau. However, captures during most of 1991 and 1992 indicated the species was permanently established on the island. Further evidence of a breeding population was provided by collections of infested coffee fruits collected from experimental plots at Kiekie during 1992. Populations of MFF were centered in the village of Pu'uwai and the coffee patch at Kiekie. Of special interest during this survey was the recovery of marked sterile flies at 7 of the 10 survey sites that had been released on Kaua'i (Vargas unpubl. data) 60 km upwind of Ni'ihau. These captures document movement of flies between the islands of Ni'ihau and Kaua'i. These distances are similar to those reported for OFF movement among islets of the Ogasawara Islands by Iwahashi (1972).

ACKNOWLEDGMENTS

We thank the Robinson family for permission to survey the island of Ni'ihau for fruit flies; Bruce Robinson, for his help in selecting trap sites, collecting data, and providing information on Ni'ihau Island; Tom Mishler, David Nekomoto, and George Stever, the

helicopter pilots, for their expert flying; Charles Rodd and John Spencer, Tropical Fruit and Vegetable Research Laboratory, USDA-ARS, Kapa'a, Hawai'i, for traps and lures; and Dale Kanehisa, Tropical Fruit and Vegetable Laboratory, USDA-ARS, Honolulu, for assistance in processing data. We also thank John W. Beardsley, Toshiyuki Nishida, and Grant Uchida, Department of Entomology, University of Hawaii at Manoa, Honolulu, Hawai'i, and William Walsh, Oceanic Institute, Waimanalo, Hawai'i, for critical reviews of an earlier version of this manuscript.

LITERATURE CITED

Armstrong, R.W. 1983. Atlas of Hawaii. University of Hawaii Press. Honolulu. 238 p.

Beardsley, J.W. & L.D. Tuthill. 1959. Additions to the known insect fauna of Niihau. Proc. Hawaii. Entomol. Soc. 17: 61.

Harris, E.J., J.M. Takara & T. Nishida. 1986. Distribution of the melon fly, *Dacus cucurbitae* (Diptera: Tephritidae), and host plants on Kauai, Hawaiian Islands. Environ. Entomol. 15: 488–93.

Hinds, N.E.A. 1930. The geology of Kauai and Niihau. Kraus Reprint, Millwood, New York. 103 p.

Iwahashi, O. 1972. Movement of the Oriental fruit fly adults among islets of the Ogasawara Islands. Environ. Entomol. 1: 176–79.

SAS Institute. 1985. SAS user's guide: statistics. SAS Institute, Carey, North Carolina.

Uchida, G.K., R.I. Vargas, J.W. Beardsley & N.J. Liquido. 1990. Host suitability of wild cucurbits for melon fly, *Dacus cucurbitae* Coquillett, in Hawaii, with notes on their distribution and taxonomic status. Proc. Hawaii. Entomol. Soc. 30: 37–52.

Vargas, R.I., E.J. Harris & T. Nishida. 1983a. Distribution and seasonal occurrence of *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae) on the Island of Kauai in the Hawaiian Islands. Environ. Entomol. 12: 303–10.

Vargas, R.I., T. Nishida & J.W. Beardsley. 1983b. Distribution and abundance of *Dacus dorsalis* (Diptera: Tephritidae) in native and exotic forest areas on Kauai. Environ. Entomol. 12: 1185–1189.

Vargas, R.I., J.D. Stark & T. Nishida. 1989. Abundance, distribution and dispersion indices of the oriental fruit fly and melon fly (Diptera: Tephritidae) on Kauai, Hawaiian Islands. J. Econ. Entomol. 82: 1609–1615.

Vargas, R.I., J.D. Stark & T. Nishida. 1990. Population dynamics, habitat preference, and seasonal distribution patterns of oriental fruit fly and melon fly (Diptera: Tephritidae) in an agricultural area. Environ Entomol. 19: 1820–1828.

Wichman, R.J. & H. St John. 1990. A chronicle and flora of Niihau. National Tropical Botanical Garden. Lawa'i, Kaua'i, Hawai'i. 157 p.

Manuscript submitted: 3 Apr. 1993
Manuscript accepted: 5 Nov. 1993